AEI

Electrical Distribution

THE NEWS MAGAZINE OF THE CABLE AND CONSTRUCTION (CABLES & LINES) DIVISIONS OF ASSOCIATED ELECTRICAL INDUSTRIES LTD

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EDITORIAL

ROAD RESEARCH MAY seem miles away from the electrical engineer's normal country, although traffic-light applications are commonplace and road heating is becoming so. But the report of the Road Research Board (H.M.S.O., price 7s. 0d.), published for the Department of Scientific and Industrial Research, highlights another interesting aspect.

This is the development of vehicle detectors, which indicate the presence of a moving or stationary vehicle. One type utilizes the change in mutual impedance between an energized (2kc/s) loop of cable and a second loop, caused by the presence of metal. A second type of detector takes advantage of the Hall effect in a semiconductor whereby a small change in the earth's magnetic field caused by ferromagnetic metal in the vicinity is detected.

The value of vehicle detectors allied to light signals at the approach to roundabouts is being investigated. When vehicle flow is approaching stand-still point, automatic switching of signals to "all red" should at least save tempers among drivers actually on the roundabout. Those behind the lights would be fuming anyway.

Another item in the report is concerned with the "impact value" of street lighting columns. For high-speed roads, a column which allows the car to survive is favoured and the thin sheet-steel type has been found best. Tests were conducted by running 8h.p. saloon cars into the columns at 22m.p.h. The "score" of cars per column or *vice versa* is not revealed.

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OUR COVER PICTURE

Berkeley Nuclear Power Station is shown on this month's cover. It is one of Britain's commercial reactors and is situated by the River Severn, in Gloucestershire. The station is the subject of an article on page 159.

News in brief...

A.E.I.'s Prizewinning Film

Electron Microscopy—an Introduction, A.E.I.'s first scientific film, gained second prize in the Scientific Research in Industry category and three special awards at the Second International Industrial Film Festival held in Turin this year.

The film surveys the history of microscopy and explains the principles behind modern electron microscopy, which uses a beam of electrons focused by electromagnetic coils to observe objects much too small to be seen by even the most powerful light microscope.

The construction of the EM6 electron microscope designed by A.E.I. is shown and the film demonstrates its use with the image intensifier, another A.E.I. development which opens up the possibility of observing individual atoms. *Electron Microscopy* also shows how specimens are prepared and some of the microscope's many uses in research and industry.

As can be seen, the film is explanatory in treatment and should prove of great use to students, undergraduates, and graduates, as well as being of exceptional interest to those in industry who wish to gain some knowledge of the subject.

Cable Renewal for B.R. Southern Region

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED has been awarded a £105 000 contract by the British Transport Commission for renewing existing power feeders on five sections of Southern Region track in the Brighton and Sevenoaks areas. The work will be carried out by A.E.I. Construction (Cables and Lines) Division.

The five sections lie between Keymer Junction and Pangdean, Lancing and West Worthing, and Chelsfield and Sevenoaks. The contract involves the supply, supervision of the laying, and jointing of 33kV 3-core oil-filled cable, with aluminium conductors and corrugated aluminium sheath.

Copper for Radiant Heating

Copper for Radiant Heating is the title of a valuable new publication (No. 60) issued by the Copper Development Association. It covers radiant heating by means of embedded hot-water pipes and by sheathed electric cables.

Floor warming by cables, using either m.i.c.c. or withdrawable cables, is dealt with at some length. A set of cable spacing charts is included in the book, relating cable length and the calculated heat requirements to heating cable loading. There is also a brief chapter on floor and ceiling construction.

The book (78 pp.) is concluded by a series of tables, often referred to in the text, which give heat transmission coefficients, typical room temperatures and air changes, and heat loss figures from windows, walls, floors, and ceilings.

Copper for Radiant Heating is obtainable free to serious inquirers from the Copper Development Association, 55 South Audley Street, London, W.1.

Dunstable Reinforcement

A £33 000 CONTRACT to supply and install 33kV and 11kV solid type cables at Dunstable has been placed with Associated Electrical Industries Ltd by the Eastern Electricity Board. The work is part of an interim scheme to reinforce the electricity supply system in the Dunstable area and includes strengthening supplies to the Rootes and Vauxhall factories at Dunstable.

The installation will involve laying three 360yd lengths of 33kV 3-core 0·3sq.in. conductor solid cable, accompanied by pilot and telephone cables; two 2 166yd lengths of 11kV 3-core 0·3sq.in. conductor solid cable, accompanied by pilot and telephone cables; and two 16yd runs of 11kV single-core 0·75sq.in. conductor cable, with three cables per run.

A.E.I. Construction (Cables and Lines) Division will install the cables, which will be manufactured at the Gravesend and Woolwich factories of A.E.I. Cable Division.

Visual Aids to Maths Teaching

ASSOCIATED ELECTRICAL INDUSTRIES (Manchester) Limited has produced an illustrated full-colour forty-four-page booklet on Visual Aids which have been designed to give an understanding of simple arithmetical, algebraical, and geometrical relationships by demonstration. These aids will be helpful in the teaching of mathematics in Secondary Schools and Technical Colleges, and to young Craft Apprentices.

The information upon which this booklet is based was most generously given by the Siemens and Halske Works School in Berlin, who provided facilities for two staff members of the A.E.I. Manchester Works School to study a comprehensive range of Visual Aids.

The aids described in the brochure are now being used in the A.E.I. Manchester Works School, and a number of demonstration lectures have been given to various organizations.

Copies of the booklet can be obtained on application to the Education Manager, Group Personnel Services, Associated Electrical Industries (Manchester) Limited, Trafford Park, Manchester 17.

VOLTAGE LEVELS IN MULTI-VOLTAGE POWER SYSTEMS

From tie-line voltage level to consumer's terminal voltage

by **A. SALZMANN**, Dipl.Ing., A.M.I.E.E.

Introduction

Generally, the power received by consumers is of high quality if (a) continuity of supply is maintained, (b) constant system frequency is secured, and (c) the voltage applied to consumer terminals is maintained within statutory limits regardless of load variations. Dealing in this paper with voltage problems only, the voltage level of the entire system should be considered from the point of view of maintaining the consumer's terminal voltage within statutory limits but not ignoring operational requirements for various transmission sections such as tie lines between generating stations and transmission and distribution lines. For instance, it is essential that reactive power interchange between stations should be so adjusted that voltages on the system remain stable. In fact, generating of reactive power should take place at load centres, particularly when long transmission lines are involved, while power interchange between stations should be achieved at high transmission power factor.

As an illustration, let us consider a typical power system shown in Figure 1. For the short interconnector, denoted by IC, plus step-up and step-down transformers T_A and T_B, having a total resistance R, reactance X, negligible charging current, and transmitting active power P kW at lagging p.f., the voltage drop expressed in percentage is equal to

$$\Delta E\% = \frac{P}{10V_B^2}(R + X\tan\phi) \quad \ldots\ldots\ldots (1)$$

where V_B = line-to-line voltage (kV) at the receiving end, station B, and ϕ = transmission p.f. angle. Dividing this equation by R, we can write

$$\Delta E\% = \frac{PR}{10V_B^2}\left(1 + \frac{X}{R}\tan\phi\right) = \frac{PR}{10V_B^2}(1 + \tan\alpha\tan\phi) \quad \ldots (2)$$

where α represents the impedance angle of the transmission elements. This formula gives the relationship between the three variables: (1) active power P, (2) transmission p.f. $\cos\phi$, and (3) percentage voltage drop ΔE. For low transmission p.f., $\tan\phi > 1$ with import of large blocks of reactive power to station B, the voltage drop is considerable, according to equation 2. Thus if it is desired to transfer active power P from station A to B, more steam is admitted to turbines at A, permitting voltage V_A to advance on V_B, say by an angle β at a given p.f., a certain amount of reactive current is to be transferred from A to B. In this way we can determine the voltage drop and the voltage level of the system.

In the above equation the first term can be disregarded because of $X/R > 1$. If angle α or ϕ or both are increased, the voltage drop tends to become predominantly reactive: i.e. we may write $\Delta E\% = PX\tan\phi/10V_B^2 = QX/10V_B^2$ and the transmitted reactive power $Q = P\tan\phi$ becomes a function of ΔE. It should be noted that the reactive power flow is controlled by the difference in magnitude of the voltage $\Delta E = V_A - V_B$ applied to the interconnector and is from the point of higher voltage V_A to lower voltage V_B. Voltages V_A and V_B are controlled by ratio adjustment of the step-up and step-down transformers, shunt capacitors, boosters, or by adjusting the field current of the generators.

Thus reactive power interchange between generating stations controls the system voltage. If the reactive supply, denoted by Q_S, and demand Q_D are equal: $Q_S - Q_D = 0$, the system voltage remains stable. For $Q_S > Q_D$—perhaps during night-time at low load and owing to the capacitance effect of large cable networks, we have $Q_S - Q_D = Q_R$, where Q_R represents the surplus leading reactive supply. In this case the system voltage will rise. By increasing the lagging reactive supply in a similar situation during night-time by connecting shunt reactors in order to reduce the leading charging current, voltage stability is restored. We have again $Q_S - Q_D = Q_R = 0$. Alternatively, Q_R can be reduced to zero by disconnecting some cable networks. For $Q_S < Q_D$, say at load centres demanding large imports of reactive power or, alternatively, during the peak at times of heavy load, the voltage level of the system becomes lower. Add reactive supply ΔQ and the system voltage rises again and voltage stability is restored. Obviously, the voltage level of the system is subjected, to variations owing to surplus (or lack of) reactive supply.

In h-v transmission and distribution networks, the voltage level can be raised or lowered by ratio adjustment of the step-up and step-down transformers. This method of compensating the voltage drop is limited by the range of the tap-change transformers and has to be supplemented by other voltage-regulating devices, such as synchronous condensers or switched capacitors.

Of great importance is a regulated voltage level on h-v distribution feeders since the bulk of consumers is fed from this feeder, while large industrial and commercial loads, relatively few in number, are supplied from the transmission line.

Finally, for l-v networks the aim is to maintain adequate consumer terminal voltages regardless of load

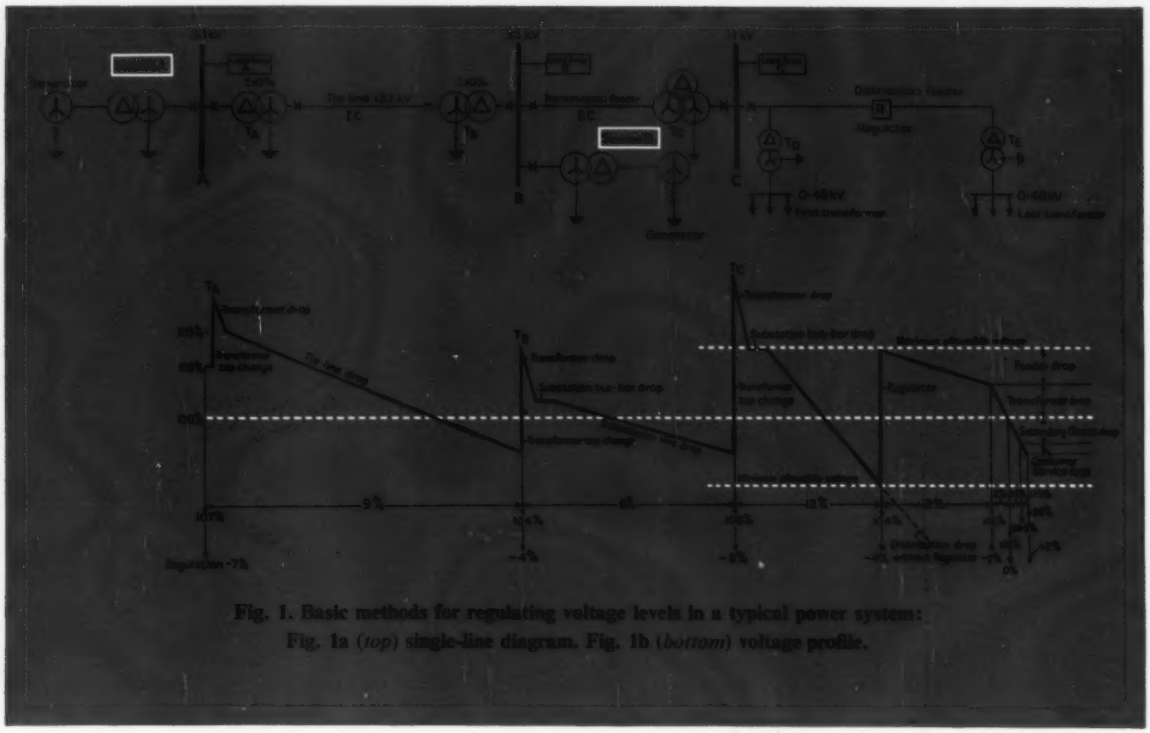

Fig. 1. Basic methods for regulating voltage levels in a typical power system:
Fig. 1a (*top*) single-line diagram. Fig. 1b (*bottom*) voltage profile.

variations. In some cases individual feeder regulators will be required, particularly when feeders of considerable length are involved. In the following pages we shall deal with various voltage levels in multi-voltage power systems.

Voltage profile of transmission and distribution feeders[1]

Since power flows from the source of supply to load centres, the transmission and substation elements will transform the power from transmission voltage to consumer voltage, but at the expense of lowering the voltage levels due to voltage drop and system losses. These voltage drops must be corrected by means of voltage regulating devices. It is essential that correct proportioning of voltage drops from the last consumer back to the source of supply should be enforced automatically by voltage correcting devices throughout the power system. However, transmission and distribution elements may introduce voltage regulation limitations due to operational requirements.

Further, if it is required to maintain predetermined voltages in load centres a line-drop compensator must be incorporated in the circuit. The compensator produces a voltage drop equivalent to the line voltage drop to the load centres in a voltage-regulating control circuit proportional to the load current. In this manner we increase the output voltage by initiating the transformer tap-change motor to insert or remove portions of transformer windings during periods of peak load and decrease the output voltage during periods of light load.

A useful tool for analysing voltage levels to be considered is the voltage profile. The latter is shown in Figure 1b for a typical power system during peak load with allocated voltage drops along transmission and distribution elements.

For clarity's sake we assume a large voltage drop along the h-v distribution feeder, say 12%, to illustrate the application of feeder regulators. The magnitude of voltage correction is a function of the load cycle of the system and, if the voltage drop is corrected adequately, the consumer's terminal voltage will be maintained within satisfactory limits.

Notice that the voltage profile indicates whether the voltage along the distribution feeder falls below the minimum allowable voltage level. Where the distribution feeder voltage approaches the permissible minimum value supplementary voltage regulating devices should be located. (Regulator R in Figure 1.) The latter should raise the voltage to the maximum value. In fact the optimum location of the regulator should be ahead of the permissible value in order to provide for some load growth.

Voltage level at generating stations

At generating stations the effect of applying load, consequently lowering the voltage level from its normal value at the bus-bars, is met by a corresponding automatic instantaneous rise in the field current in the least possible time. Quick-acting voltage-regulating devices

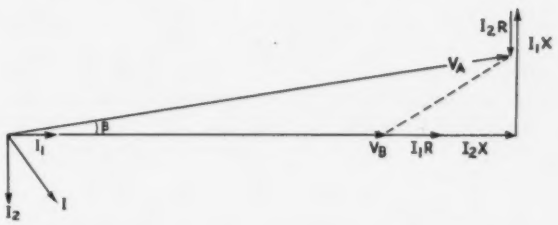

Fig. 2. Vector diagram illustrating transfer of active and reactive power.

and high-speed exciters should secure stable internal generator voltages under normal system conditions and during periods of system faults and emergency loads.

Generally, the voltage level at generating stations can be controlled by combined transformer tap-change and alternator field current change. If the voltage level is raised, say at station A, Figure 1, via tap-change transformer T_A only, to give $X\%$ boost towards the high-voltage side while the step down unit T_B operates on normal tap ratio (assuming generation takes place at both stations), the reactive demand on station A will be increased. This is due to the presence of an unbalanced voltage which will force a circulating current around the circuit T_A—IC—T_B, the latter being reactive since the resistance R of the transmission elements is negligibly small compared with the reactance.

However, if the internal generated voltage is raised by increasing the generator field current, station A will supply more reactive current and the higher-voltage side will be raised still more. On the other hand, if the field current is reduced until the low-voltage side is lowered by $X\%$, the reactive current will be decreased and so eliminate the lagging reactive current caused by $X\%$ boost of tap-change unit T_A. In this way $X\%$ tap-change in transformer T_A is cancelled by lowering the bus-bar voltage at A.

Similarly, if a tap-change is made at A to give $X\%$ buck, the decrease of the reactive current can be eliminated by increasing the generator field current by $X\%$. In this way $X\%$ tap-change in transformer T_A is cancelled by raising the bus-bar voltage at A.

Interconnector or tie-line voltage level[3]

Earlier we pointed out that the consumer's terminal voltage should be related to voltage levels, particularly those on h-v distributors, and the latter in turn to those on transmission and tie lines. As an illustration, let us consider Figure 1 again and assume that generation takes place in both stations A and B and that active and reactive power is transferred via a short tie line from A to B, as illustrated in the vector diagram Figure 2. Consider the current I as two components—namely I_1 in phase with the receiving-end voltage V_B, and I_2 in quadrature with this voltage. Then for given voltage levels V_A and V_B and displacement angle β we have an in-phase voltage drop $\Delta E_i = I_1R + I_2X$ and quadrature voltage drop $\Delta E_q = (I_1X - I_2R)$. Thus the transfer of reactive current depends on the voltage difference ΔE_i, while active power is a function of ΔE_q at the phase displacement angle β.

It is apparent that we can raise or lower the tie-line voltage level by applying ratio adjustment of the step-up and step-down transformers, assuming the nominal ratio is $n = 132/33$ (see Figure 3). For maximum tap ratio for unit T_A at the sending end, the no-load voltage ratio is equal to 145/33 or $\{(132/132)145\}/33 = 145/132n = t_s n = 1{\cdot}1n$ and the minimum tap ratio for unit T_B at the receiving end is equal to $119/33 = \{(132/132)119\}/33 = t_r n = 0{\cdot}9n$, where t_s and t_r are ratio correction factors and equal to (tap ratio/nominal ratio) >1 or <1.

It follows that the maximum regulation range is of the order $145 - 119 = 26$kV. In the case where the voltage drop exceeds the value $\Delta E = 20\%$, both units T_A and T_B will operate at the extreme ends of their tapping range and consequently the voltage at the receiving end cannot be maintained constant.

A point of interest is that raising and lowering the system voltage level is possible without the addition of reactive power if tap-changes are co-ordinated by making equal changes in tap settings on both units A and B.

Fig. 3. Equivalent circuit for step-up and step-down transformers shown in Fig. 1.

As an illustration, let us consider an example. We assume $V_A = V_B$; generating takes place at both power stations; transmission is from A to B and both transformers are initially at nominal ratio. A tap-change on unit T_A gives, say, $X\%$ boost towards the higher-voltage side, assuming the field current of alternator A is maintained constant. Raising the voltage means an increase of the transformer ratio, the ratio correction factor t_s=(tap ratio/nominal ratio)=$\{n+(X\%n)100\}/n$ being larger than unity and the no-load voltage on the higher-voltage side is equal to $V_1 = V_A(n_1/n_A)t_s = V_A n t_s$. Since unit T_B still operates at nominal tap ratio while voltage V_A has been raised, the existence of an unbalanced voltage will force a circulating current to flow around circuit T_A—IC—T_B and hence the reactive demand on station A is increased.

Now if a similar voltage boost is applied to the step-down unit T_B towards the higher-voltage side, the transformation ratio is increased by the same amount as on unit T_A, the unbalanced voltage becomes zero and the increase of the reactive demand on station A will be eliminated. In this manner one can raise the voltage level of the system without adding reactive current.

In a similar manner, tap-change on units T_A and T_B, giving $X\%$ voltage buck, will lower the voltage level of the system without decreasing the reactive current.

Finally, attention should be given to interconnectors associated with transformers and forming a closed loop. Correct operation is secured if:

1. The product of all the transformation ratios of the step-up and step-down transformers within the closed loop is equal to unity.
2. The sum of all the phase-shift angles caused by transformers within the loop and having different interconnection is zero.

Transmission feeder voltage level

Again let us consider the network illustrated in Figure 1 (feeder BC) where we assume that voltage at B is maintained constant. Here automatic on-load tap-changing gear is incorporated in substation transformer T_C. Assuming the latter has a tap range $\pm C\%$, the voltage level at bus-bars C can be maintained at V_c provided that the voltage drop ΔE_{BC} along the transmission line BC, including transformer T_C, is less than $C\%$ because of the tap range $\pm C\%$. For $\Delta E_{BC} = C\%$ the voltage level at bus-bars C is raised automatically to V_c by adjustment of the transformer tapping on the h-v side—that is by reducing the turn ratio by $C\%$. If it is required to maintain a predetermined voltage level in area C and along the h-v distribution feeder CE, line-drop compensation associated with a voltage regulating relay has to be used in conjunction with the on-load tap-change equipment of unit T_C.

As pointed out earlier, the voltage at the receiving end (h-v side) is $t_r n V_c$, and hence on bus-bars C it is $t_r n V_c / n t_r$. In fact, this voltage is smaller than V_c because the current flowing through the transmission line BC, plus unit T_C, is increased from $I = I_L/(V_B/V_C) = I_L/n$ to $I' = I_L/(nt_r) = I/t_r$ where I_L=line current and n=nominal ratio=V_B/V_C. This is due to changing the transformation ratio. Thus for $t_r < 1$ the line current becomes larger and consequently the voltage drop ΔE_{BC} increases from $C\%$ to $C/t_r\%$. As regard change of transformer reactance due to tap position, variation of the latter can be disregarded as its influence to the total system reactance is negligible.

It should be noted that the on-load tap-changing transformer T_C is a star-tertiary-star connected unit. For the improvement of the operational requirements we can utilize switched shunt capacitors connected to the tertiary winding, should the voltage drop ΔE_{BC} become larger than the tap range $\pm C\%$ and there are no spare taps at hand.

Thus maintenance of the voltage level at bus-bars C by means of adjusting the turn ratio of transformer T_C has its limitation, particularly if feeders with large reactance and low transmission p.f. are involved (see equation 2). Static capacitors in conjunction with on-load tap-change transformers should be considered as supplementary voltage-control devices. Also capacitors reduce system losses and relieve system loading.

Distribution feeders and low-voltage network voltage levels

The solution of distribution and low-voltage problems is complex, particularly for rural power systems. Maintenance of good consumer voltage levels means obtaining best possible illumination from lamps, better performance from induction motor and heating appliances, and last, but not least, increased revenue to the supply undertakings. It is obvious that voltage-correction methods have to be adopted in order to maintain the consumer's terminal voltage within satisfactory limits regardless of load variations. This can be achieved in several ways: (a) using regulators; (b) converting single-phase feeders to 3-phase construction; (c) using static balancers; (d) increasing conductor sizes; (e) employing static capacitors, and finally (f) increasing the number of substations.

As an illustration, let us consider the distribution circuit shown in Figure 4, assuming transformer T_D is removed from the circuit. Statutory regulations permit a voltage variation at the consumer's terminal of $\pm 6\%$ the declared voltage (240V). On-load tap-change substation transformer C gives, say, automatically 5% voltage rise between no load and full load. Distribution unit T_E, on the other hand, has taps on the higher-voltage side giving $\pm 2{\cdot}5\%$ and $\pm 5\%$ and a standard lower voltage of 250V which, in effect, gives a fixed boost of 4%, as the declared voltage is 240V. The voltage drop of this circuit for full-load conditions is assumed as follows:

Distribution feeder 6%; transformer T_E 3%; secondary circuit plus l-v mains 7%; consumer circuit 1·5%: making a total drop equal to $-17{\cdot}5\%$. The voltage variation at consumer's terminals is therefore from -6% to $+4{\cdot}75\%$ and hence within statutory limits as shown in Table 1 overleaf.

This proves that a total voltage drop of 17·5% from the

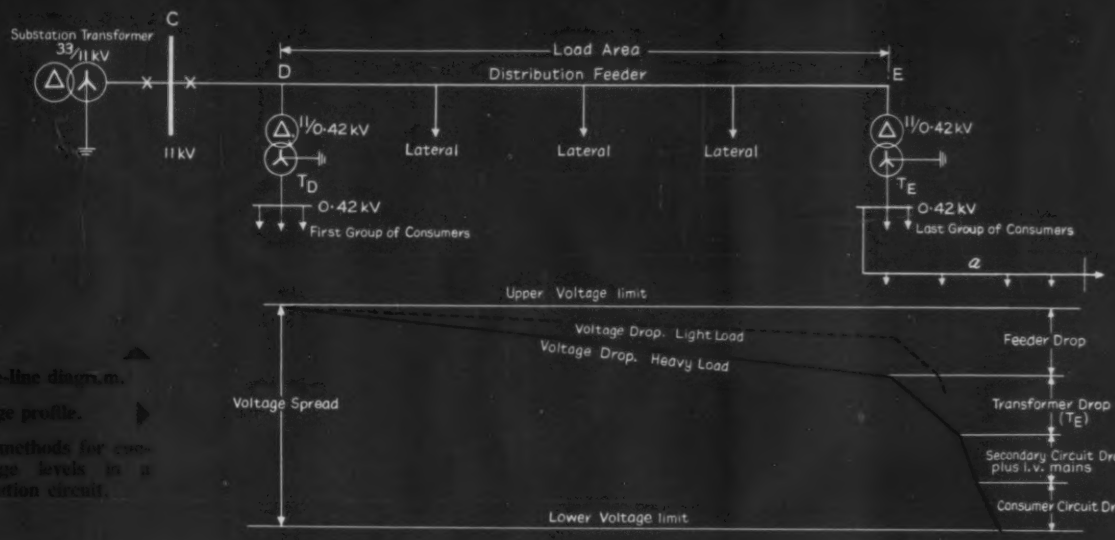

Fig. 4a. Single-line diagram.

Fig. 4b. Voltage profile.

Fig. 4. Basic methods for controlling voltage levels in a typical distribution circuit.

Table 1

Voltage: drop, boost, and variation		*Full load* %	*Light load* 10%
Voltage boost	Substation transformer	+5·0	0
	Distribution transf. T_B fixed boost	+4·0	+4·0
	Distribution transf. T_E h-v tap $-2\frac{1}{2}\%$	+2·5	+2·5
Total voltage drop		−17·5	−1·75
Voltage variations at consumer's terminals		−6·0	+4·75

source of supply C to consumer's terminals is tolerable.

Reconnecting unit T_D but with the latter loaded lightly, we have about the same voltage conditions as outlined above, because the drop in transformer T_D and its lower-voltage circuit is negligibly small but the last unit T_E remains fully loaded. Consumers connected to the first transformer T_D have therefore a maximum voltage level, while the consumers supplied from the last transformer T_E have a minimum voltage level. Thus the difference between consumer terminal voltages is voltage spread S—namely, the range between maximum and minimum voltage levels between first and last transformers, which is related to distribution transformer loading and distributed load along the distribution feeder.

Generally, a voltage spread of $S=10\%$ on overhead lines is an average value and the division of this drop may be about 5% in the distribution feeder between the first and last transformer; 3% in the last transformer; 1·5% in its secondary circuit (short l-v main), and 0·5% in the consumer circuit. These values will differ on underground systems or l-v mains of considerable length.

It is essential that adequate primary voltages should be secured by (a) a main substation transformer associated with voltage-correcting devices; (b) supplementary regulation, such as individual feeder regulators and capacitors, and (c) fixed boosts and no-load ratio adjustment in the distribution transformer. When more than one feeder is supplied from the bus-bar C and voltage on the individual feeders cannot be held within prescribed limits under full- and light-load conditions, then individual feeder regulation should be considered. This applies particularly to various types of feeders with different load cycles, such as those supplying industrial and residential loads. Individual feeder regulation is independent of the regulation of other feeders and holds the voltage level within satisfactory limits.

Finally, in considering light-flicker, it should be emphasized that the latter cannot be eliminated by voltage-correcting devices. The increased use of thermostatically controlled heating devices, motor-driven appliances, such as are used in starting large motors, or employing welding equipment, causes light-flicker to consumers connected to the same transformer. Banking of transformers paralleling on the secondary side, a number of units or, alternatively, using an adequate section of copper, or series capacitors should be considered as remedies.

Returning to Figure 4 which illustrates a rural distribution circuit: with the aid of the voltage profile we can examine the voltage levels starting from the last consumer terminal voltage back to the source of supply, the primary of the distribution transformer. To provide all consumers along the 11kV feeder (assuming uniformly distributed load) with a voltage spread of, say, $S\%$, the line-drop compensator and voltage-regulating relay associated with tap-change equipment of the main distribution transformer C have to hold automatically a predetermined voltage constant at the upper limit in its circuit—call this point D.

For clarity we have neglected, in the voltage profile Figure 4b, the bandwidth (the difference between upper

and lower settings) of the voltage-regulating relay. In fact, these settings must be related to the substation transformer tap-change steps, to avoid lamp-flicker during a tap change. Steps must be small—say 1·25%—but the bandwidth of the voltage regulating relay must be larger than one step to avoid unstable conditions. This regulating device starts to correct the voltage it is holding when it has changed, say, ±1·3%. Thus, within the bandwidth, no tap-change operation takes place. Excessive operation due to momentary fluctuations causing the voltage to go out of the bandwidth can be prevented by incorporating a time delay in the voltage-regulating device.

From inspection of the voltage profile (Figure 4b), we see that at heavy-load periods along the distribution feeder, the group of consumers connected to the first transformer T_D receive the highest voltage. At the same time the consumer group connected to the last transformer T_E receives the lowest voltage. However, if the difference in consumer terminal voltage under, say, heavy- and light-load conditions is large, the voltage-regulating device should be reset to a higher voltage value so that we apply to unit T_D increased voltage (overcompensation) as the flow of the load through the feeder increases. This will give a satisfactory average voltage to the consumers along the feeder under light- and heavy-load conditions.

Alternatively, by readjusting the voltage-regulating relay and the settings of the line-drop compensator, and selecting a remote point from the substation for maintaining constant voltage regardless of load variations, the difference in consumer terminal voltage under any load condition may become very small.

Finally, it should be pointed out that distribution feeder circuits are more complex than shown in Figure 4. First of all, the load is not uniformly distributed and, secondly, the laterals may have additional branches. In this case the heavy-load voltage profile must be examined to find out whether the voltage falls below the minimum permissible value. This will enable us to determine the rating and location of supplementary voltage-correcting devices.

Voltage levels on 3-phase 4-wire low-voltage distributors

Here, single-phase currents flow in 3-phase circuits, the latter being unbalanced. This results in increase of the voltage drop in the heaviest-loaded phase, for example at new housing estates where a number of single-phase circuits are teed off from a 3-phase 4-wire l-v mains and the distribution limit is governed by the voltage drop (see Figure 4a, feeder *a*). Obviously this problem cannot be analysed on the assumptions that: (a) The loads have a maximum value; (b) The loads are uniformly distributed, and (c) the loads are balanced among the phases.

Regarding loads, according to J. L. Egginton,[4] tests made in 1956 showed that "after diversity maximum demand" (a.d.m.d.), namely

$$\frac{\text{Maximum demand of } n \text{ consumers}}{\text{Number of consumers}}$$

is about equal to 2kW per house. Obviously some consumers will take more and some less than 2kW. A practical rule giving the total load for n consumers is $P=8+n(\text{a.d.m.d.})\text{kW}=8+2n\text{kW}$.

Regarding voltage drop, ΔE_U with unbalanced load, tests have shown that ΔE_U is obtained if the balanced load voltage drop is multiplied by a factor $f=1+1{\cdot}4U$. If both unbalanced load and non-uniformly distributed load are taken into account, the balanced load voltage drop is to be multiplied by a factor $f=1+1{\cdot}38U(1+1{\cdot}4U)$ in order to obtain ΔE_U. In these formulae unbalance U is defined as

$$U=\frac{\text{Resultant unbalanced load in the neutral } (P_s)}{\text{Average load per phase } (P/3)}$$

$$=\frac{2}{\sqrt{P/3}}$$

Consider distributor *a* Figure 4 supplying forty houses. Total load is $P=8+2{\cdot}0\times40=88\text{kW}$ hence $U=2/\sqrt{29{\cdot}3}=0{\cdot}37$. The increase in voltage drop is therefore $f=1+1{\cdot}4U=1{\cdot}53$, i.e. the effect of unbalance is voltage drop increased by 53%. With unbalance and non-uniform load distribution, the voltage drop will be increased by $f=1+1{\cdot}38U(1+1{\cdot}4U)=1{\cdot}78$ (78%).

Practical example: The 3-phase transmission and distribution network shown in Figure 5 supplies substations A and B. Load demand on substation A is 6MVA lagging, p.f. 0·8, and on substation B 1·2MVA lagging, p.f. 0·8. The system data are given in Table 2 overleaf and the effect of system capacitance is negligible. Determine the voltage levels on the bus-bars in order to maintain a phase voltage at consumer's terminal C equal to 240V.

Solution: A first approximation is to determine roughly the voltage drop of the entire system, in order to select transformation ratio adjustment on units T_A and T_B. Using the trial-and-error method, a reduction of the turn ratio on transformer T_A by, say, 7%, and on unit T_B by 5% will secure an approximate voltage level of 33kV at the sending end for the given load conditions.

Fig. 5. Single-line diagram of a typical transmission and distribution circuit

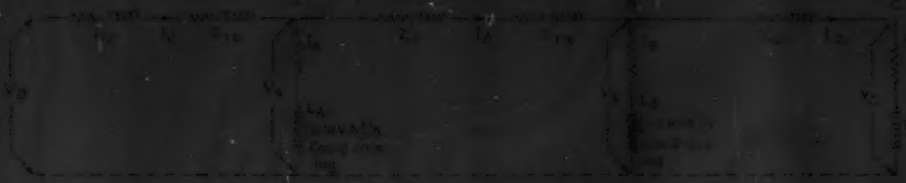

Fig. 6. Single-phase equivalent circuit of the system shown in Fig. 5

Table 2: System Data

Line sections transformer loads	*Rated voltage line/phase kV*	*Line: Length of cross-sectional area Transf: Rating. Nominal tap ratio Loads: rating*			*Impedance ohms*
a	0·415/0·24	0·25in.	U/G	300ft	0·012 7+j0·009 09
b	11/6·35	0·15in.	O.H.L.	5 miles	1·475+j2·75
c	33/19·1	0·15in.	O.H.L.	5 miles	1·475+j2·75
T_A	33/11; 19·1/6·35	10MVA	33/11	30·69/11	1·09+j9·8*
T_B	11/0·415; 6·35/0·24	2·5MVA	11/·415	10·450/·415	0·24+j1·95*
Loads	0·415/0·24	(1) 0·15MVA	$\cos\phi=0·8$	lag	—
	0·415/0·24	(2) 1·2MVA	$\cos\phi=0·8$	lag	—
	11/6·35	(3) 6·0MVA	$\cos\phi=0·8$	lag	—

* Ref. to 33kV

Considering single-phase loading, as shown in Figure 6, we get:

Line current for the last consumer: $I_c=1/3\{(150\times0·8-j150\times0·6)/0·24\}=167-j250$A

Phase voltage at bus-bars B: $V_B=240+(167-j250)(0·001\,23-j0·009\,09)=242·48+j1·21\simeq243$V scalar

Single-phase power input to line section a: According to the convention, lagging reactive power will be minus by multiplication of the conjugate voltage $\dot{V}_B=242·48-j1·21$ and non-conjugate current I_c.

Thus we obtain

$L_a=V_BI_c=\{(242·48-j1·21)(167-j250)\}10^{-3}=40·202-j60·9$kVA.

Adding algebraically to I_a the shunt load $1/3\,L_B$, we get the power input to section *a:* $L_{Pa}=L_a+1/3L_B=40·202-j60·9+320-j240=360·2-j300·9$kVA

Current on the $0·24kV$ *side:* $1/0·243(360·20-j300·9)=1\,480-j1\,230$A

Current on $11/\sqrt{3}kV$ *side:* $I_b=(1\,480-j1\,240)(0·415/10·45)=58·5-j48·5$A

Voltage on $11/\sqrt{3}kV$ *side:* $243(10·45/0·415)=6\,130$V

Voltage drop on section b: $(58·5-j48·5)(1·71+j4·7)=328-j191$V

Phase voltage level on bus-bars A: $V_A=6\,130+328+j191=6\,458+j191\simeq6\,470$V scalar

Single-phase power input to line section b: $L_b=\dot{V}_AI_b=\{(6\,464-j191)(58·5-j48·5)\}10^{-3}=368·75-j325·2$kVA

Adding algebraically to L_b shunt load $1/3L_A$, we get the power input to section *b:* $L_{Pb}=L_b+1/3L_A=368·75-j325·2+1\,600-j1\,200=1\,968·75-j1\,525·2$kVA

Current on the $11kV$ *side:* $1/6·47(1\,968·75-j1\,525·2)=304-j236$A

Current on the $33/\sqrt{3}kV$ *side:* $I_c=(304-j236)(11/30·69)=109-j84·5$A

Voltage on the $33/\sqrt{3}kV$ *side:* $6\,470(30·69/11)=18\,000$V

Voltage drop section c: $(109-j8\,415)(2·56+j12·55)=1\,339+j1\,154$V

Voltage level at the sending end: $V_e=18\,000+1\,339+j1\,154=19\,339-j1\,154\simeq19\,340$V scalar

Regulation: section c: $1/18\,000(19\,340-18\,000)100=7·45\%$

Regulation: section b: $1/6\,130(6\,470-6\,130)100=5·5\%$

Regulation: section a: $1/240(243-240)100=1·25\%$

Conclusion

Consumer's terminal voltage in a multi-voltage power system should be maintained stable, irrespective of load variation and the voltage levels of the entire network. On tie and transmission lines the voltage level subjected to variations due to lack or surplus of reactive power can be maintained within satisfactory limits by interchanging reactive power between generating stations generating reactive power at the load centres.

Great importance should be attached to the regulated voltage level of distribution feeders because the bulk of consumers are fed from these.

Finally, voltage profiles should be considered as a powerful tool. The latter indicate whether the voltage along the feeder falls below the minimum permissible voltage level, thus giving the amount of ratio adjustment on tap-change units and the optimum location of voltage-correcting devices for individual feeder regulation.

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BRITAIN'S BIGGEST TRAWLER

Lord Nelson, of revolutionary design, equipped throughout with A.E.I. cables.

THE *Lord Nelson*, new 12 000-ton trawler owned by the Lord Line, a subsidiary of Associated Fisheries, has completed her first successful trip to northern fishing grounds. She brought back from her 4 000-mile maiden trip about 48 000st of fish and was away from Hull, her home port, for five weeks.

Built in Germany by Rickmers Werft of Bremerhaven, she is the first British distant-water trawler to be built for stern fishing. Her cut-away stern is reminiscent on a small scale of the factory ship of a whaling fleet; the catch is trawled to the stern where it is dropped aboard for sorting and gutting.

As she is a long-distance ship, built to exploit the rich fishing grounds beyond the reach of the smaller boats, she has stores and fuel supplies to enable her to stay at sea for forty days. Consequently, equipment is installed to enable her to preserve her catch. The *Lord Nelson* has a refrigeration plant which enables her to freeze the first half of her catch—nearly 12 000cu.ft of fish—at a temperature of 20°F. The remainder of the catch is carried wet on ice.

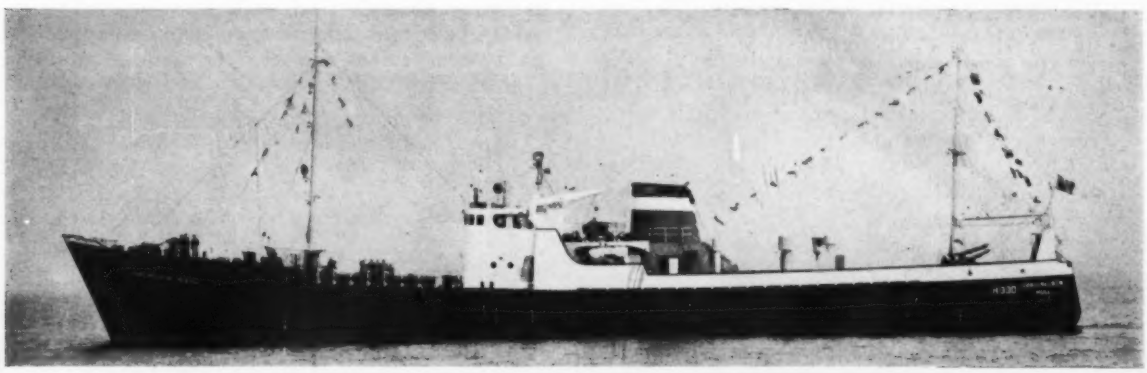
The *Lord Nelson* is 238ft long, with a 36ft beam. Her navigation and electronic fishing aids include auto pilot, course recorder, radar, and echo-sounders. Her thirty-two-berth accommodation is air heated, an electric range is fitted in the galley, and her crew appointments are luxurious by past trawler standards.

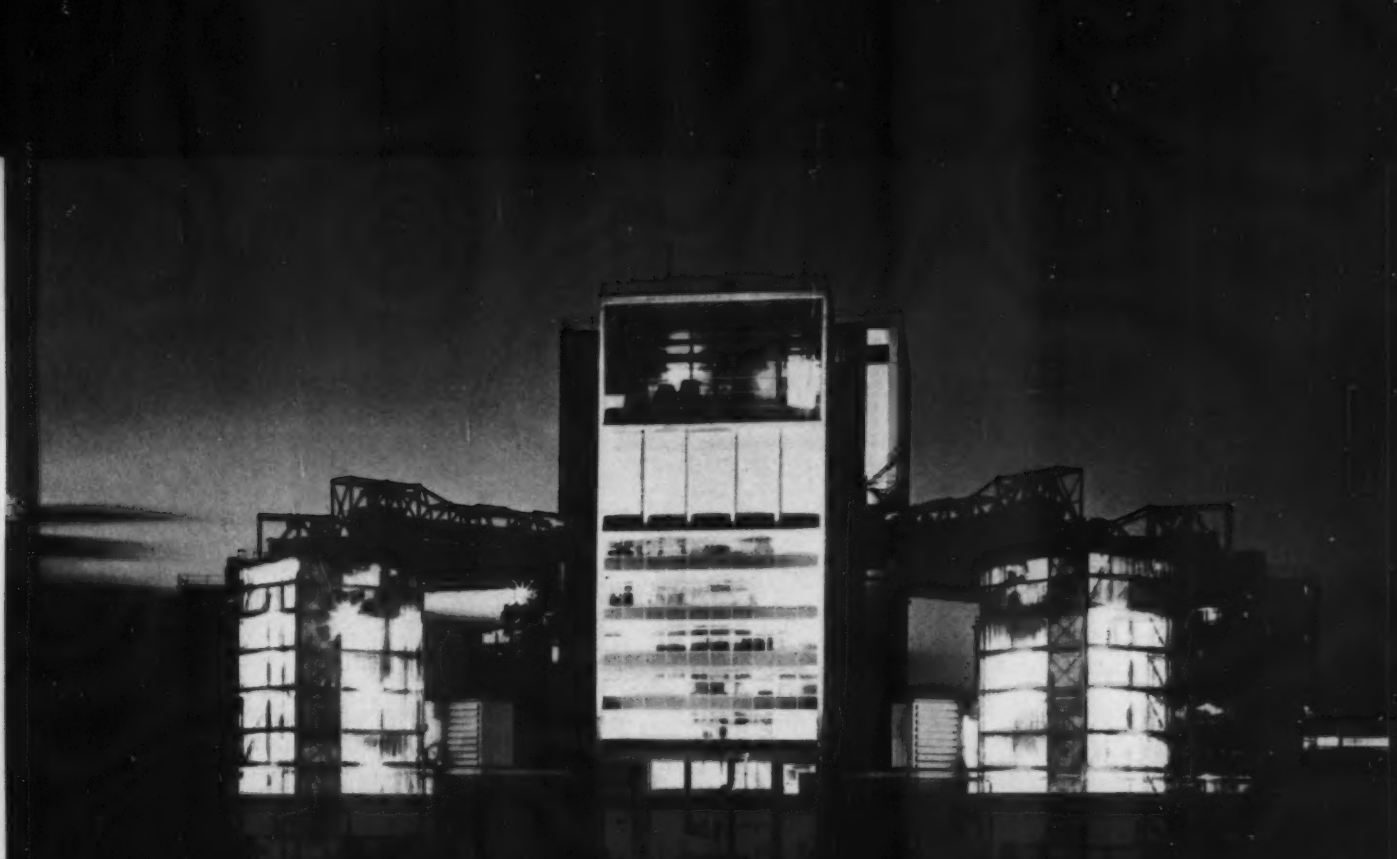
Other special equipment includes off-loading machinery for handling the 94lb blocks of frozen fish when she arrives at her home port of Hull. Twelve blocks a minute can be hoisted on deck by a continuous swing-tray elevator, to be transported by chute over the ship's side.

A.E.I. cables have been used exclusively to wire this revolutionary fishing vessel. Nearly ten miles of vulcanized rubber, varnished cambric and butyl rubber insulated ship-wiring cables have been installed.

When the ship arrived at Hull at the end of June from Bremerhaven she was the object of much admiring speculation. Her first voyage has proved the worth of this latest addition to Britain's fishing industry and will probably set the pattern for the future of long-distance trawling.

Photographs, reproduced by courtesy of the Hull Daily Mail, *show the* Lord Nelson *arriving at Hull from the Bremerhaven shipbuilders.*





BERKELEY

NUCLEAR POWER STATION

NEXT YEAR BERKELEY Nuclear Power Station's two reactors should be fully operational, feeding a net output of 275MW into the national grid. Today, after four years of site work, No. 1 reactor is loading fuel, while work on No. 2 reactor is moving to completion.

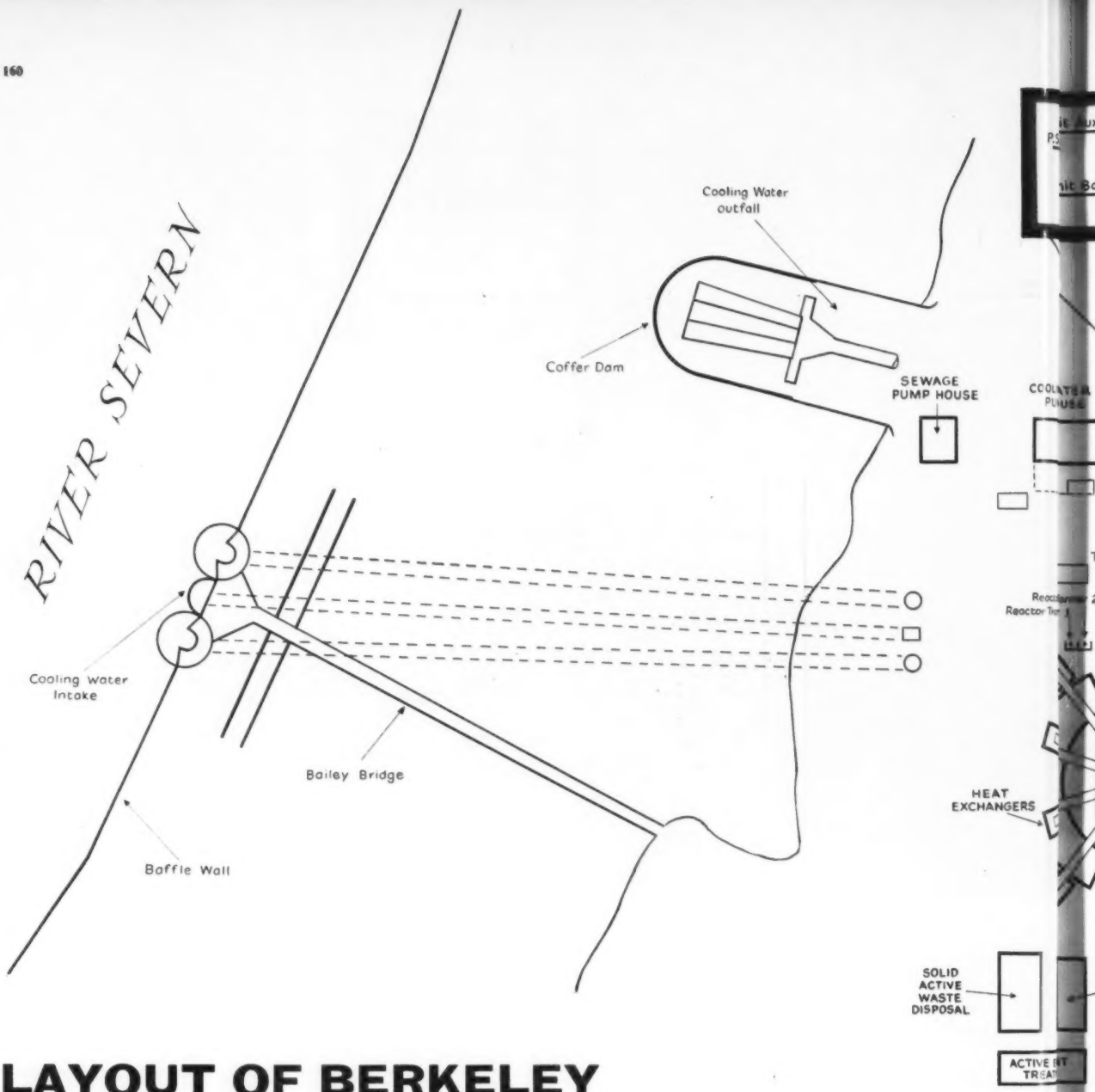
The building of Berkeley for the Central Electricity Generating Board has been accomplished by A.E.I.—John Thompson Nuclear Energy Co. Ltd, a member Company of The Nuclear Power Group. Sub-contractors for the civil engineering work were John Laing & Son Ltd and Balfour Beatty & Co. Ltd.

To accommodate the site personnel for this huge construction task, a miniature site "township" was built, consisting of bungalows for the married men and bachelor quarters for single men. This temporary village has its own cinema, public house, and recreational club.

Construction of the station on its remote sixty-acre site was no straightforward job. The site had first to be secured from floods from the nearby River Severn by raising it an average level of 10ft. An integrated construction programme, which meant working at pressure from the start of the contract, from the initial civil engineering work by the sub-contractors to the later mechanical and electrical work by A.E.I.—John Thompson Nuclear Energy Co. Ltd, saw the contractors coping with conditions which to describe as "rough" is an understatement.

Today, with the site tidied up and landscaping almost complete, the clean lines of the reactors and the station buildings show that Berkeley was planned with due regard for the amenities of the surrounding countryside.

Illustration above shows Berkeley's No. 1 reactor at night during fuel loading. This reactor was the first of Britain's commercial reactors to load.



LAYOUT OF BERKELEY

Layout

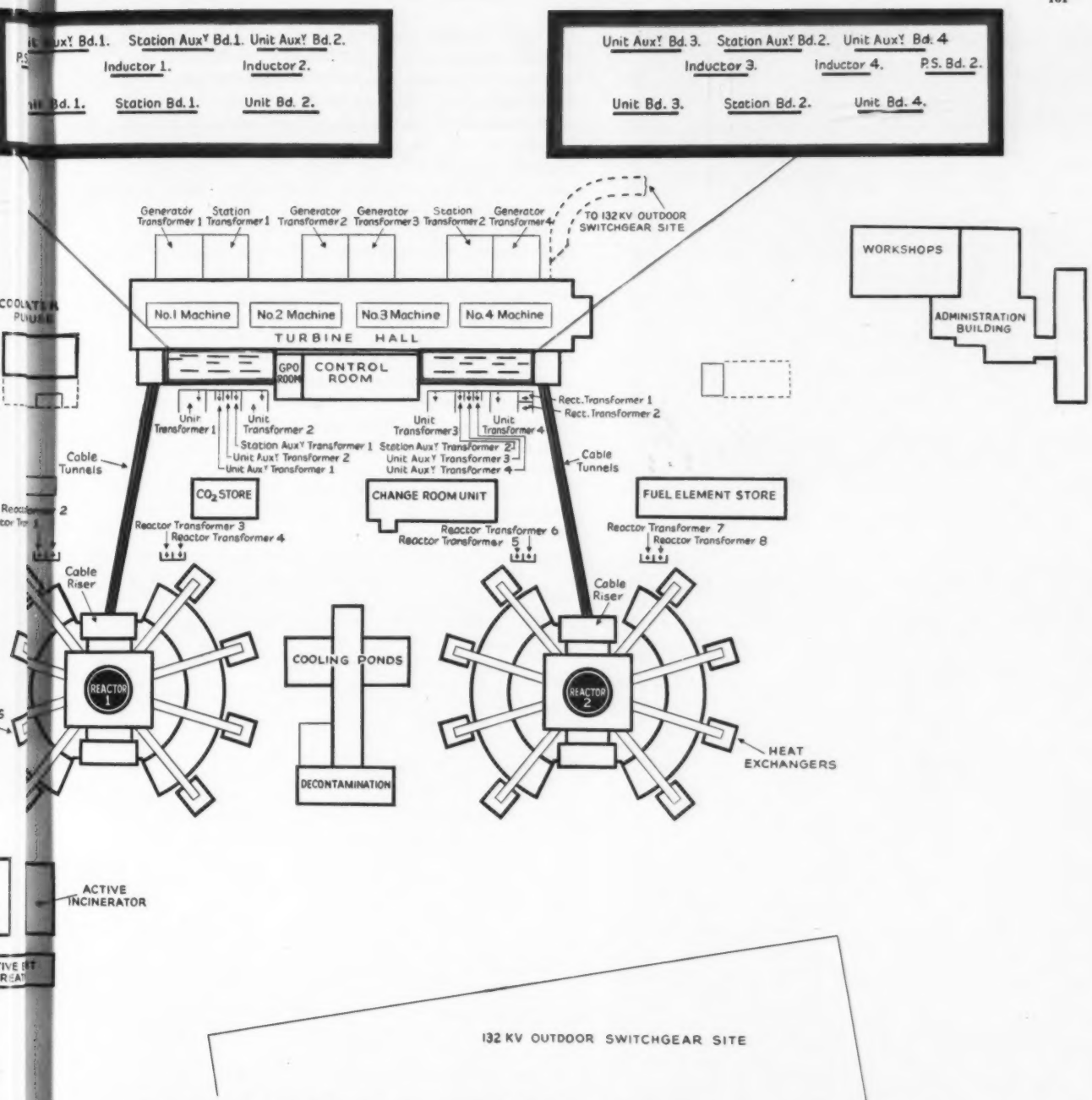
The station's two nuclear reactors are sited on a line roughly east to west, with the cooling pond for spent fuel between them.

North of the reactors stand the separate buildings of the carbon-dioxide gas store, the change room unit, and the fuel element or cartridge store; these lie between the reactors and the turbine hall which includes within its walls the centrally situated main control room.

West of the turbine hall is the cooling-water pump house; to the east lies the C.E.G.B. administration block.

From each end of the turbine hall two separate 8ft diameter cable tunnels, 230ft long and lined with cable supporting trays, go to each reactor.

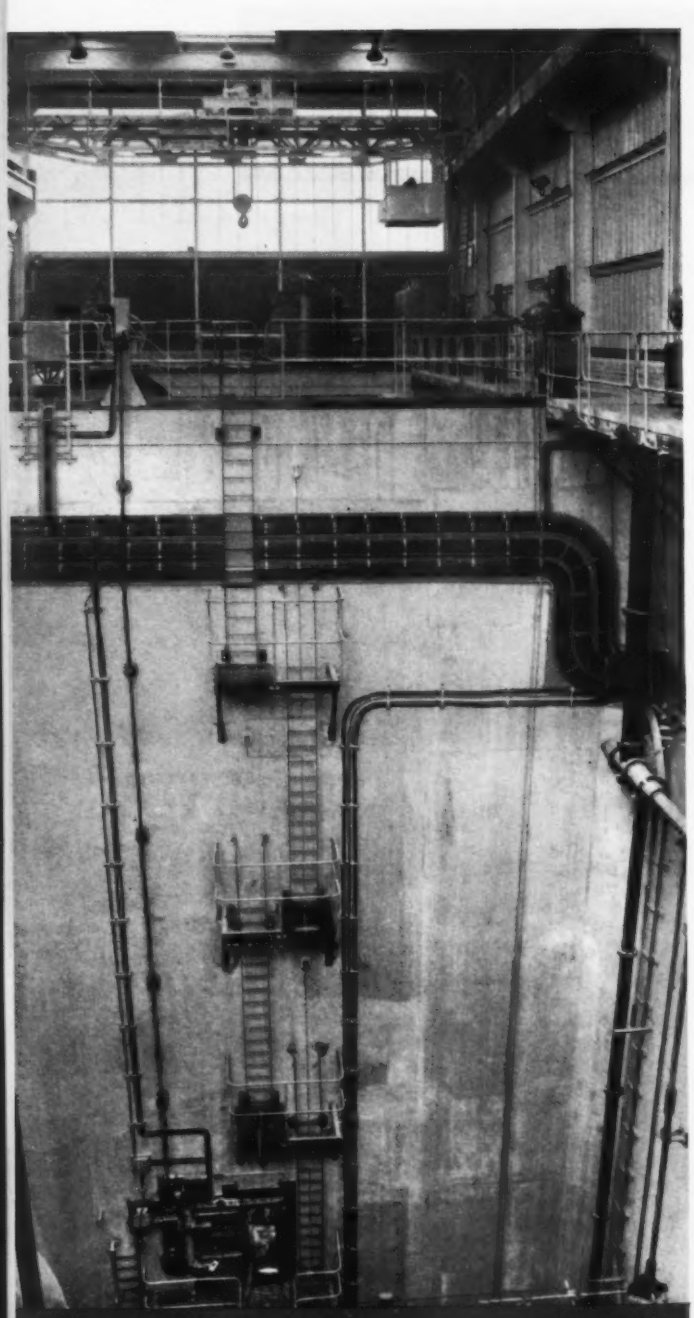
South of the reactor buildings is the 132kV switchgear compound and nearby, to the south-west of the station, are the new Berkeley Research Laboratories of the Central Electricity Generating Board.



The steel box-pile baffle wall running parallel to the bank 600ft out into the River Severn marks the water intake. From here two 10ft diameter intake tunnels connected to the cooling-water pump house provide a water supply to the turbine condensers. Inside this wall is the cooling-water outfall where the water re-enters the river from the condensers some 8°C warmer; the baffle wall prevents this warm water reaching the intake tunnels and being recirculated.

Reactors

Berkeley's two reactor buildings are each flanked by eight boilers. Each reactor is built on a reinforced concrete raft, 150ft in diameter and 14ft thick and contains a pressure vessel built of hand-welded 3in.-thick steel, 50ft diameter and 80ft high; this is cylindrical with hemispherical ends. Around the pressure vessel, which contains the graphite core and uranium fuel, is the thermal shield of two $\frac{1}{4}$in.-thick concentric steel cylinders with a



Cabling in the Cooling Water Pump House

2in. gap between them. Cooling, filtered air passing through this gap prevents the biological shield from being harmed by the heat generated in the pressure vessel. The reinforced concrete biological shield in turn surrounds the thermal shield and has a minimum thickness of 8½ft. Outside the biological shield again are the various control rooms, the fuel element preparation and inspection room, the burst cartridge detection centre, and other service rooms.

On top of the pressure vessel is a 5in. thickness of steel, a 2½in. air-gap and then 11½ft of concrete called the pile cap. Through this cap the fuel is loaded and unloaded and the control rods are adjusted by actuators contained in the pile cap.

The weight of the loaded pressure vessel is supported by 18 "A" frames at its base.

The core inside the pressure vessel is formed of accurately machined graphite blocks—about 100 000 of them placed with precision under "clean" working conditions to form a pile 48ft diameter and 30ft high. Fuel channels are arranged in an 8·16in. lattice pitch throughout the graphite for the fuel rods. There are 3 275 fuel channels. Into each channel are inserted 19in.-long, 1·1in. diameter fuel rods of natural uranium (99·3% U.238, 0·7% U.235), cased in helically finned magnesium alloy cans the whole being called a fuel element or cartridge. Thirteen of these cartridges are inserted into each fuel channel, so that a total of 42 500 cartridges is used in each reactor.

Control of the chain reaction is maintained by manipulating 132 control rods containing 4·25% boron steel. Each rod is 25ft 7in. long and 1·75in. diameter.

The eight heat exchangers served by each reactor use carbon-dioxide gas as the transfer medium to draw off the heat of the nuclear chain reaction. It is pumped round a closed circuit, between the pressure vessel and each boiler, by gas blowers through 5ft-diameter ducts at a pressure of 125p.s.i. The inlet temperature of the CO_2 gas is 160°C and its outlet temperature at the pressure vessel is 345°C. The eight blowers maintain a mass flow of 6 350lb per sec.

The heat is transferred from the gas to prefiltered water, preheated to 77°C, in the boilers. Superheated steam at 319°C is produced from the high-pressure steam drum at 305p.s.i. and from the low-pressure steam drum at 62p.s.i. Steam is collected in annular ducting at the base of the reactor and is passed over to the turbine hall.

Below and circumferential to the central pressure vessel, between the biological shield and the boilers, are arranged the two diesel standby generators provided for each reactor, and the CO_2 filters, CO_2 dryers, and axial-flow gas blowers—one set of equipment to each boiler. The power to this equipment and for the intricate instrumentation and control equipment at Berkeley is supplied through scores of A.E.I. cables laid from the turbine hall through the underground cable tunnels and accommodated in a large cable duct in the basement of the reactor building.

Turbine Hall, Pump House, and Control Room

The turbine hall, 500ft long, houses four 83MW A.E.I. turbo-generators (two per reactor), running at 3 000r.p.m. and generating at 11·8kV. About 12% of the nominal 332MW output of these machines is used to drive the sixteen 3 800h.p. CO_2 blowers, and 4% is used for other station purposes, allowing a net guaranteed output to the grid of 275MW.

Each turbine has three condensers to cope with the spent steam. The cooling water for these condensers, as already mentioned, comes from the intake tunnels on the far side of the baffle wall in the River Severn. The screened water is handled by six pumps in the pump house, each delivering 58 000 gallons a minute to the condensers. After passing around the condensers it returns to the Severn at the outfall.

The turbine hall also contains the main control room which can override secondary controls in either reactor. An assistant shift charge engineer is in charge of the central desk, while in front of him are two operators seated at a large console which records the operating characteristics of the plant.

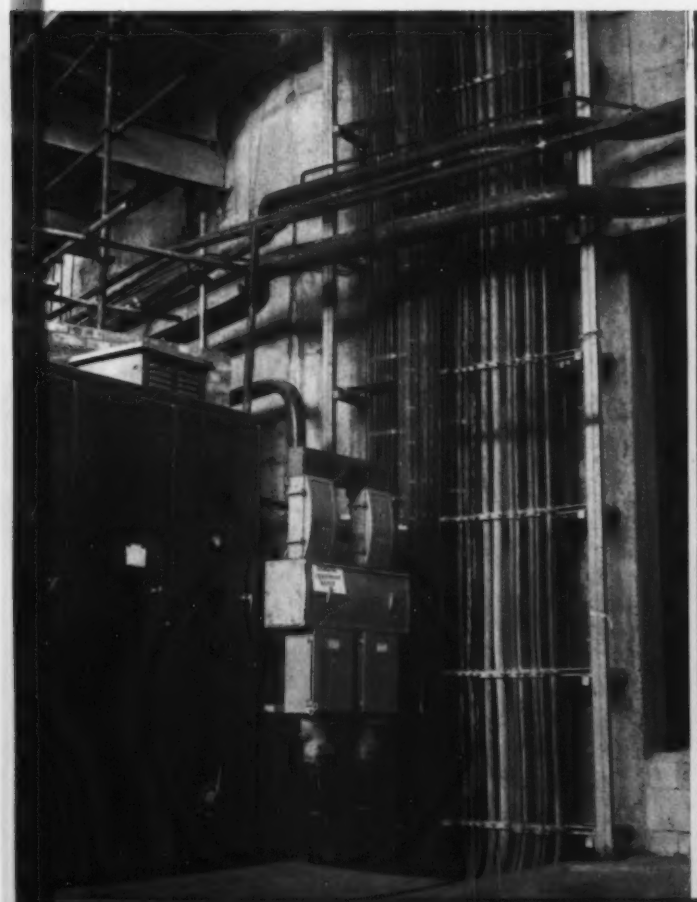
In front of the console is the equipment which controls and monitors the sixteen heat exchangers. To the right and left is automatic recording and control equipment which keeps a constant check on the physical characteristics of the reactor cores. Behind the console is the equipment for controlling the grid supply and the 6·6kV ancillary power to the station itself.

The control room is kept dust free and air-conditioned, as in the electrical circuits there are many relays whose performance would be affected by dust.

Ensuring Continuity of Performance

At Berkeley, as in any nuclear station, the reactors produce heat as a product of nuclear reaction. Reactors cannot be shut off at a turn of a switch, and hence extensive duplication, interconnection, or provision of reserve equipment is standard practice in this kind of power station. Constant voltage is absolutely necessary for the operation of sensitive equipment, and cable sizes are ample to avoid any suspension of fluctuations in supply. Again if, for example, any item of control equipment should become unserviceable it will "fail to safety" and reserve equipment will take over.

One important monitoring duty is that of the burst

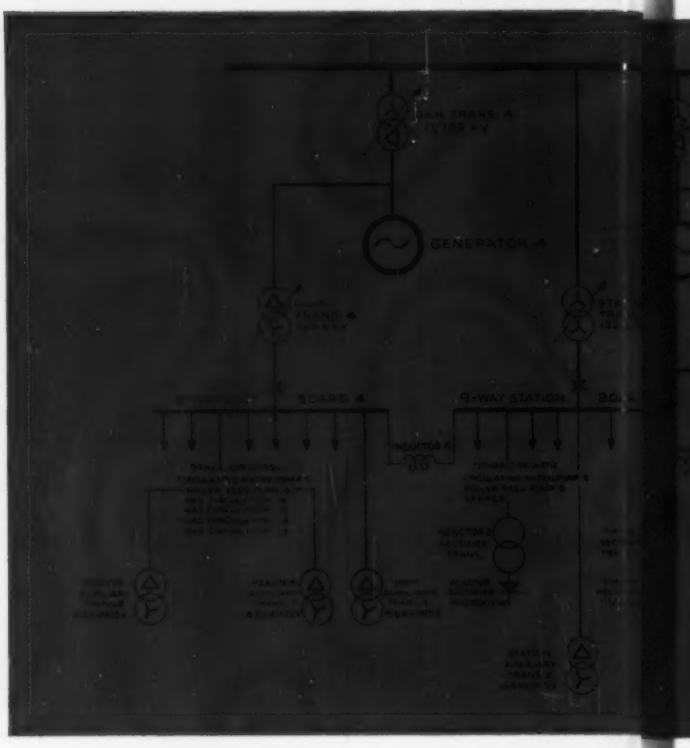


▲ Cables rising to the reactor board from the blower house basement. Centre are two main feeders entering link chambers of the 110V low-current supply ring equipment.

▲ West end of the turbine hall showing the turning area where the cables enter the cable tunnels to reactor 1.

cartridge detection equipment. Should a fuel cartridge develop a minute puncture, contamination of the gas circuits would result. If allowed to proceed unchecked, such contamination would impair the efficiency of the reactor. Therefore monitoring and eventual removal of the faulty cartridge becomes necessary.

Each fuel channel in the graphite core is therefore monitored by a stainless-steel tube, the end of which is located adjacent to the mouth of the channel. Every thirty minutes a burst cartridge detector valve samples the gas from a group of four channels and passes it to a precipitator. In the precipitator the gas sample passes over a rotating wire at high voltage and if any contamination products are present in the gas they are deposited on the wire and sensed by a radiation detector (scintillation counter). A signal is sent by the detector to a central computer system and then several things happen at once: an audible warning is given, the computer indicates in which group of four channels the fault lies, and the detector valve indicates which one of the four channels is affected. At the charge face this information is received and the cartridges in the faulty tunnel are removed as required and replaced by fresh cartridges.



Cabling

There is no place throughout Berkeley where A.E.I. cables are not to be found, for constant reliable power supplies are essential, and monitoring of equipment goes on night and day.

Since 1958 A.E.I. Construction (Cables & Lines) Division has been installing power cables in the station and its sub-contractors, Messrs N. G. Bailey & Co. Ltd, have installed a variety of control cables.

Besides the main station contract of installing approximately seventeen miles of power cables, the Construction Division has supplied, laid, and jointed all the road-lighting cables, the main domestic supplies throughout the site, and the main earth cables. Two 0·3sq.in. 11kV 3-core PILCSWA and S cables were also laid and terminated by the Division to take supplies to the new Berkeley Research Laboratories.

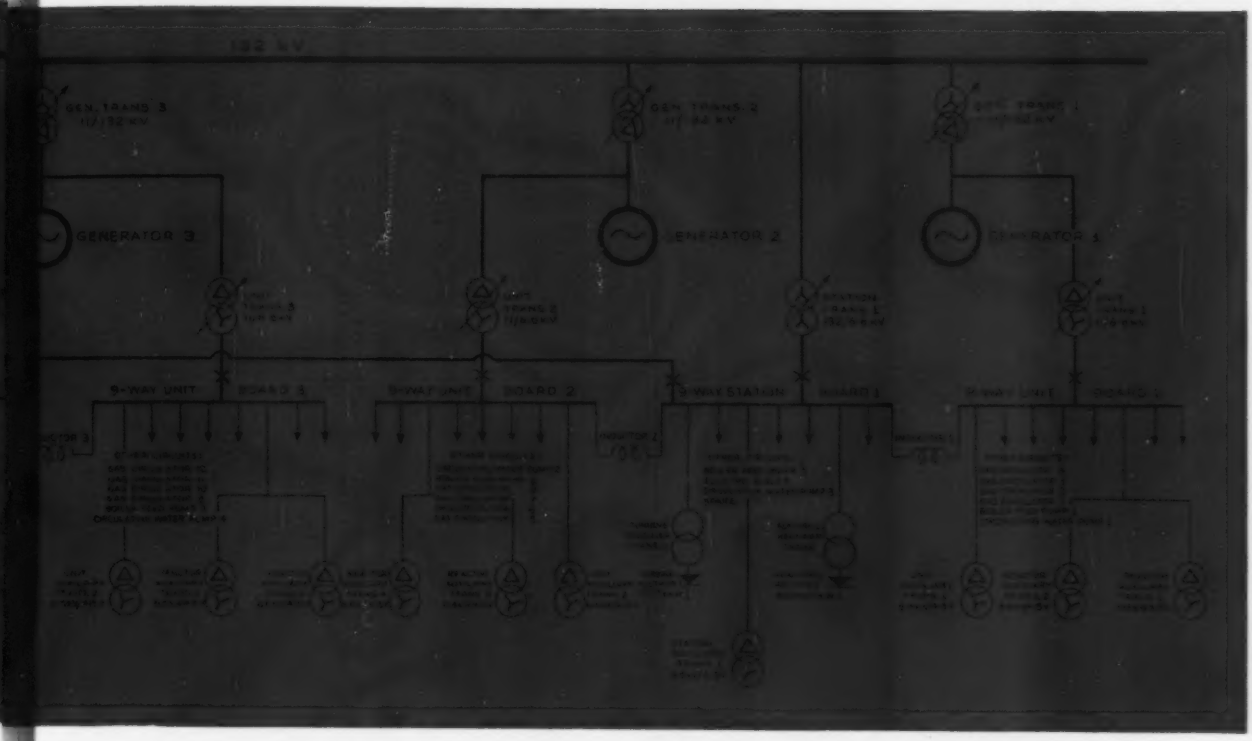
All armoured power cables, except for the few instances of cables laid direct in the ground, were specially fireproof served under the armour.

The complex runs of control and alarm cables installed by N. G. Bailey & Co. Ltd total some 300 miles. Most are p.v.c. covered, the safety cables being coloured orange for identification, and vary in size from 1-pair telephone cable to a 37-core 7/·029in. control cable. Each reactor required over 3 000 separate p.v.c. cable items and, besides this, nearly 1 000 items of m.i.c.c. cable. In addition, more than 2 000 thermocouples were installed in the reactors from the pressure vessels. Control cabling in the turbine hall and its ancillary buildings required 3 000 p.v.c. cables and nearly 200 m.i.c.c. cables.

Cabling of the cooling-water pump house comprised the first stage of the power cable contract. This consisted principally of a run of 0·3sq.in. 3-core 6·6kV cable to each of the six pumps, and other cables to the inlet and outlet valve motors.

Reactor cabling was much more complex. From the turbine hall to each of the gas blower motors, 0·3sq.in. 3-core 6·6kV PILCSWA cables were laid through the cable tunnels. With these were run five similar cables to each reactor; four to supply the 1 000kVA transformers —one for each of the four reactor m.v. distribution boards—and the fifth for a 600kV rectifier transformer. Throughout the reactors special care has been taken to ensure a firm supply to all the equipment, each reactor m.v. board being connected alternately and also interconnected with another. Should the main a.c. supply fail completely, a 4 400Ah battery can supply, via six 1·0sq.in. PILCSWA cables, all essential services until the emergency diesel generators (two per reactor) can start up and come on to load. Both reactor d.c. systems are interconnected by means of twelve 0·75sq.in. cables, some of which are served and laid direct. These cables ensure complete security of supply.

Various pieces of special instrument equipment for the reactors required a constant, never-varying supply of 110V, 50cycles a.c. For this purpose four ring mains, two of 0·3sq.in. 2-core and two of 0·15sq.in. 2-core PVCSWAPVC cables were installed. Other ring mains—three of 0·3sq.in. cables and one of 0·15sq.in. cables—laid through the cable tunnels from the reactors, supply the turbine hall instrument panels in the control room.



▲ **Berkeley: 6·6kV schematic diagram showing derivation of 415V supplies.**

A view of the control room adjacent to the turbine hall. ▶

The principal cables in the turbine hall are the main alternator cables, 1·0sq.in. PILC types, running from the four 83MW sets to the four unit transformers. From the unit transformers six 0·5sq.in. cables go to the unit boards. Again, from the unit boards 0·3sq.in. 3-core 6·6kV cables supply the auxiliary transformers, which in turn deliver 415V supplies to the ancillary equipment in the turbine hall.

Throughout the complete contract Sierack steel fixings for supporting cables and cable trays have been used extensively, with consequent savings in installation time owing to the simplicity of erecting this predesigned structural steel system.

Sidelights

"Safety" at Berkeley takes on its ultimate meaning: everything must be—and is—as safe as human ingenuity can make it. Welds have been X-rayed to ensure perfection, equipment is checked, re-checked, and checked again.

For example, the word "clean" used to describe the conditions under which the graphite core is laid, is no fanciful phrase; its interpretation at Berkeley would bring despair to the most houseproud of women. Before the first of the graphite blocks was laid in reactor No. 1 the interior of the pressure vessel was spotlessly cleaned and the atmosphere strictly controlled for temperature and humidity. After the graphite structure was completed the blowers were started and the air flow carried dirt and debris into filters in the gas outlet ducts. The only debris recovered, apart from a small amount of graphite dust, was a fine mat comprising linen dust worn off the men's white overalls. Could any housewife claim as much?

Everything at Berkeley, however, is *not* modern, for the site is unique in possessing an eighteenth-century gazebo, belonging to the Berkeley family of Berkeley Castle. Prior to the commencement of site work it was used to store pig food, but it has been retained in the general landscaping of the power station and is now preserved as a historic monument—a nice example of British consideration for the past.

The turbine hall, with the four A.E.I. turbo-generators being erected during construction of the station.

A.E.I. CABLES IN THE CARVAIR

New craft for Channel Air Bridge for service in autumn

CHANNEL AIR BRIDGE, a British United Airways company, plan a new passenger-and-vehicle air service across the Channel later this year.

The service will use the Carvair aircraft—a modification of the well-known DC-4, developed by Aviation Traders (Engineering) Ltd. It had its maiden flight for test purposes last June.

The major modification immediately obvious in the Carvair is the pronounced hump in the forward fuselage which enables up to six cars to be loaded through the nose. In addition, twenty-three passengers can be carried. Maximum weight of the Carvair, at 73 000lb, is identical with that of the DC-4. Cruising speed is about 200m.p.h.

Ten Carvairs have been ordered by Channel Air Bridge. They will fly passengers and cars from Southend across the Channel and to new destinations deep in the Continent—Lyons, Strasbourg, Dusseldorf, Bremen, Basle, and Geneva. The first service in the autumn will probably be on the Rotterdam route. Passengers will be accommodated at a standard of comfort previously unknown on cross-Channel car ferry operations.

By modifying an existing aircraft type rather than designing a new one, Aviation Traders are able to produce the Carvair for only £150 000. The conversion work includes an extremely thorough overhaul and a minute inspection of the airframe. Among the various items installed in the Carvair are A.E.I. cables.

Blockley or Gorseinon?

WHICH CHURCH—AND which village—had the first public electricity supply? The question has aroused interest among Electricity Boards.

The South Wales Electricity Board, in their magazine *Trydan*, claim that Gorseinon church in their area was the first to be lit by a public supply, in 1888. Gorseinon is situated by the River Lliw in Glamorgan.

The editor of *Midlands Electricity*, the magazine of the Midlands Electricity Board and the Midlands Region C.E.G.B., on checking old records found that the first village to have an electricity supply in the Midlands area was the village of Blockley, near Worcester. Initially this was a private supply generated by water power at Dovedale House by Lord Edward Spencer-Churchill. This must have been prior to 1887, because in that year the family wanted more electric power and a company was formed to exploit the water potential farther down the village. This company provided lighting for the village and put a light on the church tower. But the precise date when Blockley church had lighting is not recorded—it was probably some time in 1888.

Is there any advance on 1888 for a village or church lit by electricity in the British Isles? Water power as a prime mover was first used on a large industrial scale in the north of England for spinning machinery, but for the generation of electricity for domestic use, at least in the public supply sense, it would seem to have been exploited first in South Wales or the Midlands.

SWINDON CONTRACTS FOR SOUTHERN ELECTRICITY BOARD NEAR COMPLETION

NOW NEARING COMPLETION in the Newbury Sub-Area of the Southern Electricity Board is a big cabling scheme connected with the Board's new Stratton Grid substation. Considerable industrial and domestic loads are materializing at Stratton St Margaret and on the outskirts of Swindon, and this work will bring additional power supplies to the area.

The Southern Electricity Board's Stratton substation is supplied from an adjacent new Central Electricity Generating Board substation which in turn is fed from the 132kV national grid through a double-circuit overhead spur from the existing Berkeley–Oxford line.

Two contracts, with a combined value of £37 000, were awarded to A.E.I. Construction Division by the Southern Electricity Board some months ago for the supply, supervision of laying, and jointing of oil-filled feeder cables associated with the Stratton power reinforcement scheme. The two A.E.I. 33kV 3-core oil-filled cables concerned are the first oil-filled cables to be installed in the Swindon district. They feed a new factory of the Pressed Steel Company and a new substation at Park North catering for a mainly domestic load.

Feeders and pilot cables enter Stratton Grid substation laid in a short length of common trench excavated chiefly in the limestone which underlies the topsoil of the district. Inside the substation the cables are terminated in sealing ends mounted on concrete structures adjacent to oil circuit-breakers serving their respective circuits.

The two 33kV feeders turn south out of the substation and continue for some distance in a common trench with their pilot cables. Three 11kV solid type cables are laid above them in the same trench.

One of the feeders and a pilot continue south-west through a new housing estate at Stratton St Margaret to take supplies to new factory extensions of the Pressed Steel Company—a total route length of 3 445yd of 0·25sq.in. paper-insulated lead alloy sheathed, bronze tape reinforced and served cable. *En route* it passes the proposed site of a new substation intended to serve a future factory to be erected by the Plessey group of companies, into which it will be looped when supplies are required. At either end the feeder is jointed by underground trifurcating joints to separate single-core fluted lead

sheathed cables which terminate in sealing ends on the outdoor substation structures.

The other 33kV feeder, of similar construction, which is also accompanied by a pilot cable, skirts the northern boundary of the new housing estate before turning south and passing under British Railways Western Region's London–Swindon main line to terminate in the Board's Park North substation: a route length of 4 212yd between terminations. The Park North substation has been established primarily to supply the London County Council's overspill housing development at Swindon.

Culverts and railway crossings encountered on the route have been negotiated by drawing the cables through steel pipes; earthenware ducts have been used under roads, the pilot cables occupying separate pipes or ducts.

The oil-filled cables each have their separate oil systems, oil tanks being situated to suit their respective route profiles, with low-oil-pressure gauges fitted to give warning of any drop in oil pressure. The installation of this equipment and all the jointing of oil-filled cables on the contract were carried out by A.E.I. jointers.

▲ **The first of the 33kV oil-filled feeders in the trench approaching Stratton Grid Substation.**

◀ **The feeder coming off the drum 600yd away. The last yards of cable were pulled through under-road ducts at this point to a joint bay on the opposite side of the road.**

New British Standards

B.S. 3387:1961—Butyl-rubber-insulated Cables and Cords with Heat-resisting Fibre Layer

With B.S. 3258—'*Silicone-rubber-insulated cables and flexible cords*', published last year, this new standard replaces the part of B.S. 1327:1946—'*Insulated asbestos roved flexible cords*', which dealt with flexible cords insulated with vulcanized rubber and asbestos. (The other part of B.S. 1327, which dealt with flexible cords insulated with varnished cambric and asbestos, has already been replaced by B.S. 3249—'*Cables and flexible cords insulated with varnished cambric and heat-resisting fibres*'.)

This new B.S. 3387 gives requirements and dimensions for cables and flexible cords insulated with butyl rubber in association with a heat-resisting fibre layer. They are suitable for use where the combination of ambient temperature and temperature rise due to load results in a continuous conductor temperature not exceeding 100°C. *Price* 5*s.* 0*d.*

B.S. 2899 : Part 2 : 1961—Rubber Insulation and Sheath of Electric Cables. Silicone Rubber Insulation

This part of B.S. 2899 gives performance requirements for silicone rubber insulation, which is being increasingly used commercially in fixed and flexible cables and cords intended for use at conductor temperatures of the order of 150°C. Composition, physical and electrical requirements, and tests are given.

Part 1 of this British Standard (1958) deals with insulation and sheath made of natural rubber, styrene-butadiene rubber, and polychloroprene. *Price* 3*s.* 0*d.*

B.S. 2899: Part 3:1961—Rubber Insulation and Sheath of Electric Cables: Butyl Rubber Insulation and Sheath

This new part of B.S. 2899 extends the scope of the Standard to butyl rubber, which is coming increasingly into use in electric cables. Two types of insulation, one of which is ozone-resisting and suitable for high-voltage cables, and one type of sheath are specified. As in Parts 1 and 2 of the Standard, the test requirements apply to samples taken from finished cables, but optional tests for water absorption and volume resistivity at the core stage of manufacture are also included. *Price* 5*s.* 0*d.*

B.S. 3456:1961—Testing and Approval of Domestic Electrical Appliances

Sections of this specification now include electric fires, kettles, vacuum cleaners, toasters, coffee percolators, washboilers, dry shavers, immersion heaters, irons, steam irons, and hair dryers.

Copies of these Standards may be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W.1.

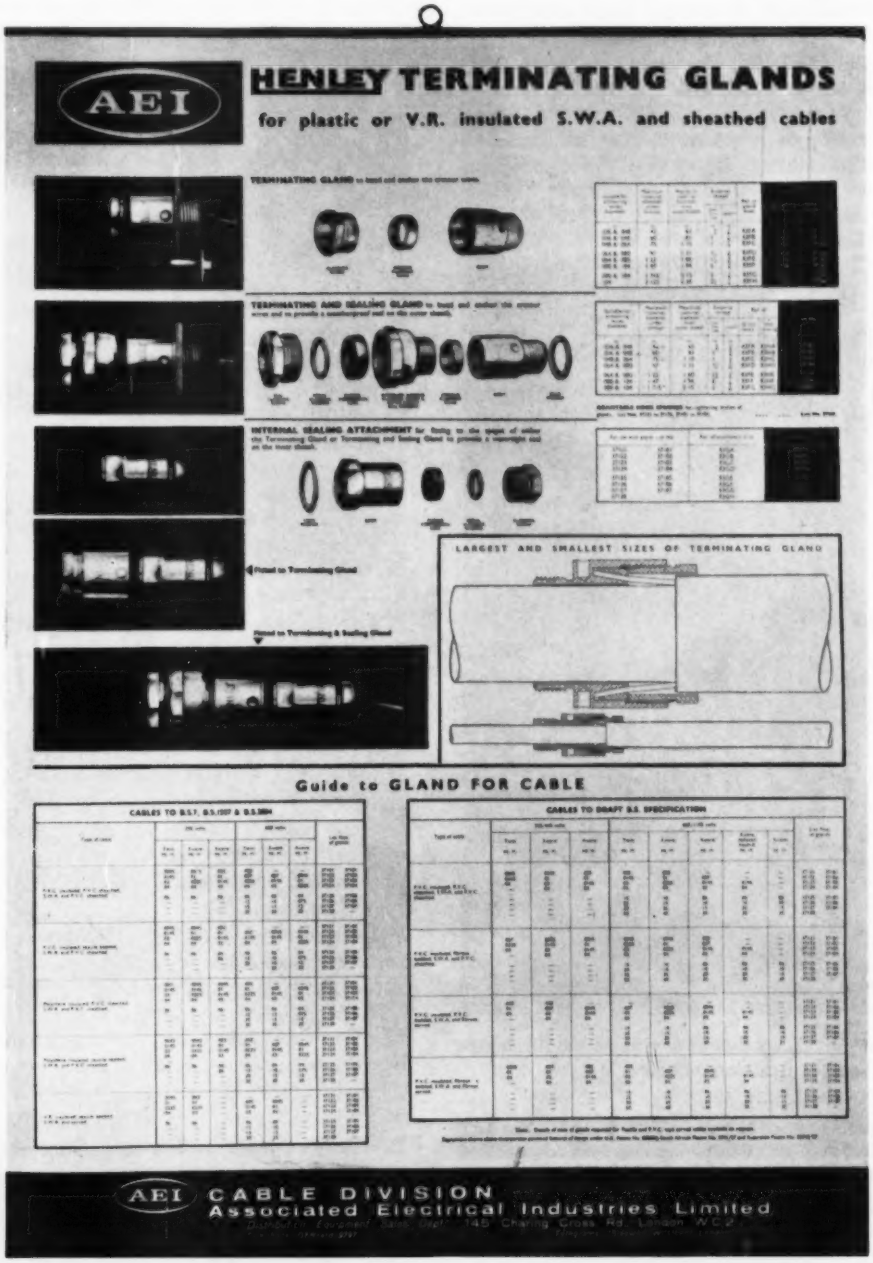
TERMINATING GLAND WALL CHART NOW AVAILABLE

NOW AVAILABLE FROM A.E.I. district offices and branches is a new wall chart issued by A.E.I. Cable Division which gives at-a-glance information about "Henley" pattern terminating glands.

Dimensions of the chart are 19in. wide by 27in. deep. It is attractively printed in three colours, and a tab for hanging is provided.

A.E.I. "Henley" terminating glands are designed for plastic- or v.r.-insulated, single wire armoured and sheathed cables. They are sold in three units: the terminating gland itself, which anchors and bonds the armour wires of the cable and gives a neat termination to equipment; the terminating and sealing gland assembly, which in addition to clamping the armour wires also gives a weather-proof seal on the outer sheath; and the internal sealing attachment which fits the spigot of either the terminating gland or the terminating and sealing gland assembly to provide a watertight seal to the inner sheath.

The wall chart shows exploded views of these three units and gives tabulated sizes and "list numbers" for ordering purposes. It also includes tables giving the maximum cable sizes accommodated by each size of gland.


AEI
HENLEY TERMINATING GLANDS
for plastic or V.R. insulated S.W.A. and sheathed cables
LARGEST AND SMALLEST SIZES OF TERMINATING GLAND
Guide to GLAND FOR CABLE
CABLES TO B.S.T. B.S.107 & B.S.88M
CABLES TO DRAFT B.S. SPECIFICATION
AEI CABLE DIVISION
Associated Electrical Industries Limited

New Leaflets Describing Cable Division Products

Leaflet EA/1—Combined switch socket outlets and fused spur units

This describes an addition to the "Siemens Ediswan" Windsor range of domestic accessories. It is a flush mounting 13A 3-pin shuttered switch socket outlet to B.S. 1363 with a 13A double-pole switched fused spur unit, mounted on a moulded front plate 5⅝in. by 3¼in. Terminals are suitable for ring circuit wiring.

Leaflet EA/2—20A Double-pole a.c. switches, surface and flush mounting

Designed primarily for the control of water heaters, these 20A double-pole switches can also be used for the control of floor heating etc. Patterns can be supplied with or without pilot lights and are also obtainable marked "WATER HEATER" and, in addition for two-gang units, "BATH" and "SINK".

Leaflet 43/K—100A "Henley" pattern double-pole insulated service fuse without sealing chamber

The well-known range of Henley insulated service fuses has been extended to include a double-pole service fuse without sealing chamber suitable for working currents up to 100A. Embodying the features of the popular Series 3–100 range, it comprises fuse and neutral with terminals suitable for conductors from 0·0145 to 0·06sq.in.

A new folder has also been produced by A.E.I. Construction (Cables and Lines) Division:

Folder CD.208—Claw-type cable cleats

This folder gives details of A.E.I. silicon aluminium claw-type cable cleats, available to suit cables from ½in. to 3in. diameter. Information given also includes sizes of backstraps, cleat-fixing studs, indented type wall bolts, and expansion bolts for use with the cleats.

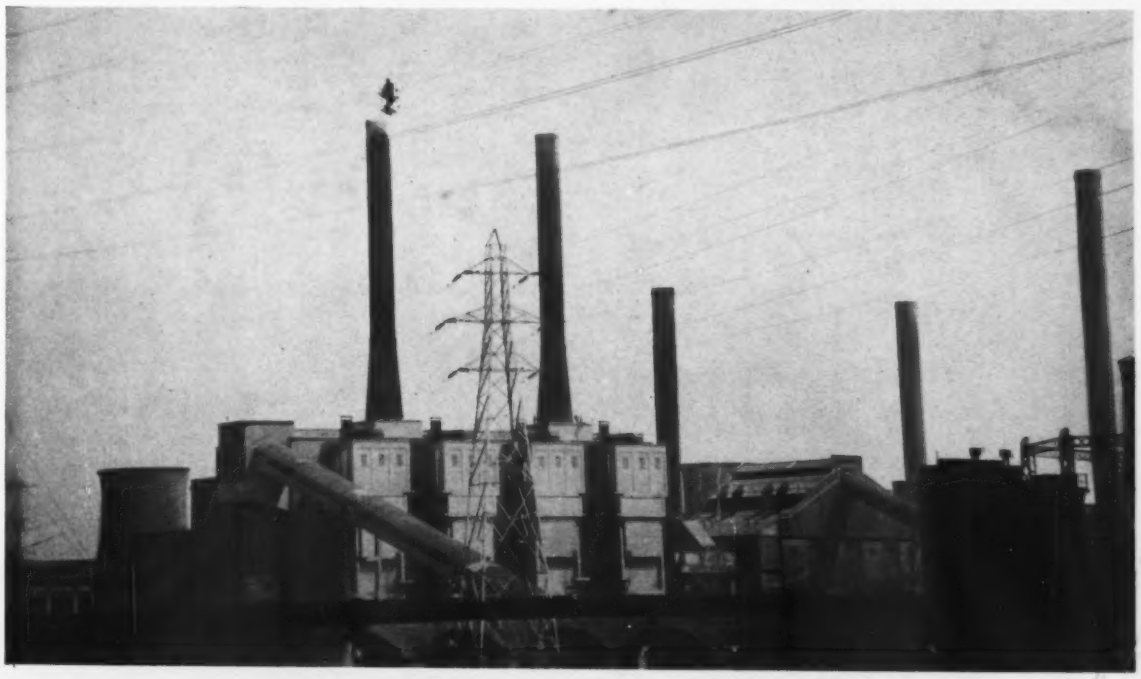
HIGH RIDER

POISED ABOVE THE industrial centre of Leicester, with Leicester generating station in the background, an A.E.I. linesman fits spacers to a span of twin 0·175sq.in. S.C.A. conductors during an overhead line contract recently completed for the C.E.G.B. Midlands and East Midlands Region.

Riding the wires is a pleasant enough job on a fine day, but one which requires a cool nerve when a cross-wind is blowing and the conductors are set swinging!

The contract at Leicester was concerned with modifications to overhead lines at the approaches to Leicester generating station. It involved the erection of double-circuit lines crossing factories, railways, a canal, and the River Soar in the centre of the city—obstacles which posed many problems in both the planning and construction stages of the work.

Photograph by courtesy of the Leicester Mercury.



? PROBLEM CIRCLE

May Overseas Competition

The overseas post-bag for Problems 5 and 6 was large —far too large to acknowledge appreciative comments singly. Each entry is read, however, and it is hoped that this collective "thank you" will be seen by all who include a personal note to the editor with their solutions.

Entries were received from all over the world—Borneo, Hong Kong, Tasmania, India, Israel, and the West Indies included.

The lucky but deserving prizewinner for **Problem No. 5** is **Mr V. R. Ananthanavayanan, Alipore Storeyard, Calcutta 27, India.** He also solved Problem No. 6 correctly.

The £1 10s. for **Problem No. 6** goes to **Mr J. S. Gamble, Box 703, Bulawayo, S. Rhodesia.**

July Problems

Problem No. 7 did not seem to draw so many "home" solutions as word sums usually do, although they give the less mathematically minded of our readers the opportunity to enter Problem Circle. The solution is:

I
AS
DAM
GUST
UNITS
ATTUNE
DISUSED
UNSUITED
ANIMATING
ESTIMATES

MAGNITUDES

The prize for this problem has been sent to **Mr M. D. Owens, 111 Bagnall Road, Old Basford, Nottingham,** who, incidentally, solved Problem No. 8 correctly as well.

Nevertheless, **Problem No. 8** gave many readers hours of enjoyment (?) judging by some of the solutions received! The grocer's unbalanced scales must have given him a headache in practice and many customers probably viewed his dexterity on the scales with admiration, possibly tinged with suspicion.

In finding the five weights required, some competitors started on a series beginning 1, 3, 9, . . . and thereafter parted company in each solution received using this approach to the problem. But the *maximum* weight which can be weighed with five weights is greater than it is possible to obtain by using this "series".

The mathematical solution given by our friend who submitted the problem is as follows, somewhat abbreviated as space is limited. Readers, however, should not have much difficulty in following the shortened explanation.

If we work out the weighing procedure for weighing $W=1, 2, 3, 4, . .$ 7lb in turn, we find that the two weights necessary for balance are $W_1=1$lb and $W_2=5$lb.

A relationship $7=\frac{1}{2}[(3^{n-1}.5)-1]$ applies, where $n=2$, the two weights w_1 and w_2 necessary to weight 7lb on the scales. Now suppose that i weights $1, 5, \ldots .(3^{i-2}.5)$ will enable the grocer to weigh from 1 to Nlb where $N=\frac{1}{2}[(3^{i-1}.5)-1]$. It can be proved that this hypothesis holds for all $i \geqslant 2$ values, so that the grocer can weigh from $W=1$ to $W=\frac{1}{2}[(3^{n-1}.5)-1]$ with the weights $w_1=1$, $w_2=5, \ldots . w_n=3^{n-2}.5$.

For $n=5$ the five weights w_1, w_2, etc. are found to be 1, 5, 15, 45, and 135lb, allowing the grocer to weigh up to $\frac{1}{2}[(3^4.5)-1]=202$lb.

The prize for this problem goes to **Mr J. R. Roff, 10 High Ash Avenue, Alwoodley, Leeds 17,** who tackled the problem in a different, but nevertheless effective, manner.

September Problems

Problem No. 9

In a room 30ft long by 12ft wide by 12ft high, all angles between walls, ceiling, and floor are perfect right angles. On one of the 12ft walls, exactly in the middle of it and 1ft from the ceiling is a lighting point. On the opposite wall there is another lighting point, again exactly in the middle, but 1ft from the floor. An electrician has 40ft of inelastic cable for surface wiring and the foreman is insistent that he uses precisely this length to connect the two points, and, furthermore, none of the cable is to hang freely in air, but all has to be neatly fastened to the walls, floor, or ceiling as the case may be. Give a solution to the electrician's dilemma.

Problem No. 10

This problem is quite simply put: without recourse to mathematical tables, show that cosine $36^\circ=(1+\sqrt{5})/4$.

Solutions to Problem Circle

Solutions to the Problems 9 and 10 should be sent to the Editor, ELECTRICAL DISTRIBUTION, Crown House, Aldwych, London, W.C.2. **Envelopes should be marked "Problem Circle".** *Closing Dates:* 20 October 1961 for competitors resident in Great Britain, Northern Ireland, and Eire. For overseas competitors the *mailing date* specified is 20 November.